having its wheels thoroughly geared up both with themselves and with those of the initial medium, so that there is no slip or dissipation of energy at the surface. In this case none of the radiation will be lost: some will be reflected and some transmitted according to ordinary and well-known mechanical laws. The part transmitted will suddenly begin to travel at a slower pace, and hence if the incidence were oblique would pursue a somewhat different path. Also, at the edges of the obstacle, or at the boundary of any artificially limited portion of the wave, there will be certain effects due to spreading out and encroaching on parts of the medium not lying in the direct path. These refraction and diffraction effects are common to all possible kinds of wave propagation, and there is nothing specially necessary to be said concerning electrical radiation on these heads which is not to be found in any work on the corresponding parts of optics.

Concerning the amount and direction of the reflected vibrations there is something to be said however, and that something very important; but it is no easy subject to tackle, and I fear must be left, so far as I am concerned, as a distinct, but perhaps subsequently-to-be filled-up, gap.

If the gearing between the new medium and the old is imperfect, if, for instance, there were a layer of slippery wheels between them, representing a more or less conducting film, then some of the radiation would be dissipated at the surface, not all would be reflected and transmitted, and the film would get to a certain extent heated. By such a film the precise laws of reflection might be profoundly modified, as they would be also if the transition from one medium to another were gradual instead of abrupt. But all these things must remain for the present part of the unfilled gap.

Electric Radiation encountering a Conductor.

We will proceed now to the case of a *conducting* obstacle—that is, of waves encountering a medium whose electrical parts are connected, not by elasticity, but by friction. It is plain here that not only at the outer layer of such a medium, but at every subsequent layer, a certain amount of slip will occur during every era of acceleration, and hence that in penetrating a sufficient thickness of a medium endowed with any metallic conductivity the whole of the incident radiation must be either reflected or destroyed: none can be transmitted.

Refer back to Fig. 43 (vol. xxxvii. p. 347), and think of the rack in that figure as oscillating. Through the cog-wheels the disturbance spreads without loss, but at the outer layer of the conducting region A B C D a finite slip occurs, and a less amount of radiation penetrates to the next layer, E F G H, and so on. Some thickness or other, therefore, of a conducting substance must necessarily be impervious to electric radiation: that is, it must be opaque.

Conductivity is not the sole cause of opacity. It would not do to say that all opaque bodies must be conductors. But conductivity is a very efficient cause of opacity, and it is true to say that all conductors of electricity are necessarily opaque to light; understanding, of course, that the particular thickness of any homogeneous substance which can be considered as perfectly opaque must depend on its conductivity. It is a question of dissipation, and a minute but specifiable fraction of an original disturbance may be said to get through any obstacle. Practically, however, it is well known that a thin, though not the thinnest, film of metal is quite impervious to light.

When one says that conductivity is not the sole cause of opacity, one is thinking of opacity caused by heterogeneity. A confused mass of perfectly transparent substance may be quite opaque; witness foam, powdered glass, chalk, &c.

Hence, though a transparent body must indeed be an insulator, the converse is not necessarily true. An insulator need not necessarily be transparent. A homogeneous flawless insulator must, however, be transparent, just as a homogeneous and flawless opaque body must be a conductor.

These, then, are the simple connections between two such apparently distinct things as conducting power for electricity and opacity to light which Maxwell's theory points out; and it is possible to calculate the theoretical opacity of any given simply-constructed substance by knowing its specific electric conductivity.

Fate of the Radiation.

To understand what happens to radiation impinging on a conducting body it is most simple to proceed to the limiting case at once and consider a perfect conductor. In the case of a perfect conductor the wheels are connected not even by friction; they are not connected at all. Consequently the slip at the boundary of such a conductor is perfect, and there is no dissipation of energy accompanying it. The blank space in Fig. 38 (vol. xxxvii. p. 345), represented a perfectly conducting layer. Ethereal vibrations impinging on a perfect conductor practically arrive at an outer confine of their medium: beyond there is nothing capable of transmitting them; the outer wheels receive an impetus which they cannot get rid of in front, and which they therefore return back the way it came to those behind them with a reversal of phase: the radiation is totally reflected. It is like what happens when a sound-pulse reaches the open end of an organ-pipe; like what happens when sound tries to go from water to air; like the last of a row of connected balls along which a knock has been transmitted; and our massive elastic wheels are able to represent the reversal of phase and reflection quite properly.

The reflected pulses will be superposed upon and interfere with the direct pulses, and accordingly if the distances are properly adjusted we can have the familiar formation of fixed nodes and stationary waves.

The point of main interest, however, is to notice that a perfect conductor of electricity, if there were such a thing, would be utterly impervious to light: no light could penetrate its outer skin, it would all be reflected back: the substance would be a perfect reflector for ethereal waves of every size.

Thus with a perfect conductor, as with a perfect non-conductor, there is no dissipation. Radiation impinging on them is either all refracted or some reflected and some transmitted. It is the cases of intermediate conductivity which destroy some of the radiation and convert its ethereal vibrations into atomic vibrations, *i.e.* which convert it into heat.

The mode in which radiation or any other electrical disturbance diffuses with continual loss through an imperfect conductor can easily be appreciated by referring to Fig. 43 again. The successive lines of slip, A B C D, E F G H, &c., are successive layers of induced currents. An electromotive impulse loses itself in the production of these currents, which are successively formed deeper and deeper in the material according to laws of diffusion.

If the waves had impinged on one face of a slab, a certain fraction of them would emerge from the other face—a fraction depending on the thickness of the slab according to a logarithmic or geometrical-progression law of decrease.

OLIVER J. LODGE.

(*To be continued.*)

PRESENT POSITION OF THE MANUFACTURE OF ALUMINIUM.

THE recent opening of new works for the manufacture of aluminium at Oldbury, near Birmingham, is distinctly an epoch in the history of this interesting metal.

The first practical steps for the manufacture of aluminium were taken in France, following the discoveries of Wöhler and of Deville, and that country has retained the monopoly of its production up to the present time. Aluminium was first obtained in a pure state in the year 1854 by St. Claire Deville whilst working in the laboratory of the Normal School, Paris, with a totally different object. Some pounds of this metal which were shown at the Paris Exhibition of 1855 had been made at the chemical works of Javel; subsequently larger plant was put up at some works at Glacière; later on we find the manufacture in an improved form transferred to Nanterre; and soon afterwards it was removed to the position in which it has ever since remained, viz. at Salindres, at the works at that time belonging to Messrs Merle and Co., but now carried on by Messrs. Pechiney and Co.

Shortly after Deville obtained aluminium by reducing the chloride with sodium, he also succeeded in isolating it by electrolyzing the double chloride of aluminium and sodium in a state of fusion. Many attempts have been made to improve this method, but although within the last year or two works have been put up both in Germany and in France which are stated to be able to produce aluminium at a comparatively cheap rate, there is no trustworthy evidence to show that they can compete with the sodium process. On the face of it there appears no reason why aluminium should not be economically manufactured in this way, since it is an undoubted fact that it can be done in the case of magnesium. There are, however, difficulties in getting aluminium to deposit in a satisfactory condition which do not occur with magnesium.

Recently, by applying electricity in a totally different way, alloys of aluminium have been manufactured on a comparatively large scale in America by Messrs. Cowles Bros. Works for the purpose are also being opened by them in England. This process, it will be remembered, consists in passing a powerful current between two carbon electrodes embedded in a mixture of alumina, charcoal, and the other metal required for the alloy. By this process aluminium in an unalloyed form has not yet been obtained, at any rate commercially.

Some fourteen years ago, Messrs. Bell Bros., of Newcastle-on-Tyne, erected works to manufacture aluminium by means of sodium; but, after incurring great expense, they abandoned the attempt, partly owing to difficulties experienced in obtaining it sufficiently pure for the manufacture of alloys, and partly because they were unsuccessful in getting it used on a sufficiently large scale. Another factory put up in Berlin was similarly abandoned, almost as soon as erected.

In America, a few years ago, Colonel Frismuth sold aluminium, which, he stated, was made by an improved sodium process of his invention; he did not, however, reduce the price, and his claims have not been substantiated. The same thing may be said of the Aluminium Company which was started about the same time in this country to work the patents of Mr. Webster, of Birmingham. It is, however, by this Company, after having undergone reconstruction, that the process is now being worked which warrants our opening statement that a fresh epoch has been reached in the manufacture of aluminium.

The process in question is the outcome of experiments commenced some six or seven years ago by Mr. H. Y. Castner in New York. He appears to have come to the conclusion that aluminium could only be satisfactorily produced by means of sodium, and he accordingly commenced work to try and improve and cheapen the manufacture of sodium. Having obtained what he considered sufficiently satisfactory results, he came over to this country about two years ago, and erected experimental works at Lambeth, where, after further trials, he succeeded in demonstrating that he was really able to produce sodium at a much cheaper rate than had before been possible; in fact, it appears he is able to produce sodium at less than 1*s.* a pound, whereas it had previously cost about 4*s.* This success led to the erection of works at Oldbury, which have been recently completed, and are now in successful operation.

In the process hitherto employed to produce sodium, an intimate mixture of carbonate of soda, lime, and charcoal is first calcined at a red heat, and this having been transferred to small wrought-iron cylinders (mercury-bottles or large gas-piping being commonly used), it is heated to about 1500° C., when the metal, having become reduced to the metallic state, distils over, and is condensed in a flat iron mould. In practice, this method is found to be defective both mechanically and chemically.

At least half the ultimate cost of production results from the wear and tear of the furnace, and the destruction of the retorts or cylinders by the comparatively high temperature. Looking at it from the chemical point of view, we find the condition of things almost as bad; little, if any, more than 40 per cent. of the sodium actually in the charge being obtained in the metállic state.

All these difficulties arise from the presence of lime in the charge, the lime being added to stiffen the mixture, and so prevent the charcoal from separating from the soda. But the thickening of the charge, which for one reason is so desirable, is equally objectionable for others. It is the thickening of the charge which necessitates the use of small cylinders and a high temperature: the material being a bad conductor, it could not otherwise be sufficiently heated. Another important difficulty in the old process arose from the presence of carbonic oxide in the gases produced in the reactions. Sodium vapour, when near its condensing-point, reacts upon carbonic oxide, forming a black refractory material which is exceedingly explosive. This is particularly the case with potassium, and is the principal reason why potassium is so much dearer than sodium.

Mr. Castner originated the idea of weighting the particles of carbon, thus doing away with the necessity of adding lime. The practical results of this modification in the method of manufacturing sodium are very far-reaching and important. The charge being perfectly fluid, it is no longer necessary to employ such a high temperature, since there is a continuous circulation of fresh material to the sides of the crucible, where the temperature is sufficiently high to set up the reactions by which the sodium is reduced to the metallic state. For the same reason large crucibles can be used instead of small cylinders. Also, the temperature of the operation being reduced from about 1400° C. to about 800° C., cast iron or cast steel may be used for the containing vessels instead of wrought iron.

The carbon particles are weighted by means of iron. The iron is first obtained in a fine state of division by reducing oxide of iron—"purple ore" being generally used for the purpose—in "producer gas," a mixture of carbonic oxide and hydrogen. The finely-divided iron thus obtained is stirred into molten pitch, which is then cooled and broken up into lumps. The next operation consists in heating these lumps in crucibles, whereby a coke is produced containing carbon and iron in the proportion of about 30 : 70; this material, technically called "carbide," having been ground up very fine, is incorporated with certain proportions of caustic soda and carbonate of soda, and the mixture is charged into large crucibles, where it is heated until the violent effervescence, due to the escape of carbonic acid and hydrogen, which takes place at first, has subsided. These crucibles are provided with holes at the bottom, closed by movable plugs. When the effervescence has ceased, the charge, in a liquid state, is run out into smaller crucibles and transferred to the furnace in which the distillation of the sodium is to take place. The preliminary heating takes about half an hour, and the actual distillation about an hour and a half.

The lid of the crucible, to which is attached the condensing arrangement consisting of an iron pipe dipping into an iron box, is fixed in the furnace; it has a convex rim which makes a joint with the grooved top of the crucible, with the assistance of a little powdered lime. The crucibles are raised and lowered by means of hydraulic power, the work of removing a crucible from the furnace and replacing it by another being done with great rapidity.

The reaction which takes place may be represented by the formula—

$$6NaHO + FeC_2 = 2Na_2CO_3 + 6H + Fe + 2Na.$$

This formula is made up in reality of several taking place *pari passu*. The main point is that it clearly expresses the final result. It will be observed that no carbonic oxide is given off, and the difficulties already referred to, caused by the presence of that gas, are got rid of. The iron is recovered, and used over and over again by coking it with fresh tar.

It is unnecessary to refer here to the arrangements for the production of the double chloride of aluminium and its reduction by sodium, as no special novelty is claimed for them.

Mr. Castner has shown great technical skill in devising the plant used throughout the works, and they are in every way a great advance on anything of the kind attempted before.

A novel feature is that hydrochloric acid, for the manufacture of the double chloride, is obtained direct by means of pipes from Messrs. Chance's glass-works, which are contiguous, and the carbonate of soda resulting from the operation in which sodium is produced is similarly conveyed to Messrs. Chance's, to be there purified and crystallized.

The estimated possible output of these works is stated to be 500 pounds of aluminium and 1500 pounds of sodium per day. The cost of manufacture of aluminium has hitherto been between 30*s*. and 40*s*. per pound. By Castner's process it is stated that it can be produced at 15*s*. That this is so there is but little reason to doubt; and it is a substantial and important reduction, which will enable aluminium to be used much more largely than has hitherto been possible. Still, before it can be very largely used, the price will have to be further considerably brought down; and it is much to be hoped that Mr. Castner's success will stimulate him and others to work with this end in view.

THE QUEEN'S JUBILEE PRIZE ESSAY OF THE ROYAL BOTANIC SOCIETY OF LONDON.

PROBABLY the last of the Jubilee productions has seen the light by the appearance of an article in the Quarterly Record of the Royal Botanic Society of London for the three months ending March last under the title of "Fifty Years of Economic Botany." The article in question forms the essay to which the Council of the Royal Botanic Society has awarded its gold medal and a purse of fifty guineas. The author is Mr. John W. Ellis, L.R.C.P. It needs only a casual glance to discover how deficient this short essay is, not only in consequence of the numerous omissions of very important plants and products, but also on account of the imperfect information given under many of the headings. Thus the writer tells his readers that China grass and rhea are two distinct fibres furnished by allied plants, the former by *Bœhmeria nivea* and the latter by *B. tenacissima*, while the fact is that China grass and rhea are one and the same thing, *B. tenacissima* being a synonym of *B. nivea*. In a casual reference to "Moong" fibre the author is apparently quite ignorant of the fact that its botanical source is *Saccharum munja*, Roxb. New Zealand flax (*Phormium tenax*) is introduced under textiles, but why is not apparent, for the author concludes his paragraph as follows—"Not having been introduced during the period to which this essay refers, any further mention of this interesting fibre—for which it has frequently been attempted to find a place in the British market—is unnecessary." Why "gun cotton and its derivatives" should occupy a special chapter it is difficult to say, seeing that this explosive substance is not a direct product of the vegetable kingdom; the author however apparently looks upon it as a much more important vegetable product than the species of cinchona, the ipecacuanha, coca, jalap, or the multitude of new drugs that have occupied such a prominent place in men's minds for the last twenty years. The success that has attended the acclimatisation of the cinchonas in our Indian possessions, whither they were introduced some twenty or thirty years since, when there was a great fear lest the supply of bark from South America should fail because of the great demand, and the consequent reduction in the price of quinine from a guinea to its present price of two shillings per ounce, are facts of sufficient importance, one would think, to be noted in any record of the progress of useful plants. And the same might also be said with regard to *Erythroxylon Coca*, considering to what purpose cocaine is now being put, but the author—a member of the medical profession—has apparently a wholesome dread of drugs, and for once has ignored all consideration of them. He seems to have been content to consult very old books for his facts throughout and to have completely passed over modern authorities; consequently his statements are both antiquated and incorrect.

The old name of *Siphonia elastica* is quoted for the Para rubber plant instead of the now better known name of *Hevea brasiliensis*. Balata is referred to *Sapota Mulleri* instead of *Mimusops globosa*, and we read that Mr. Jenman's report on the Balata Forests of British Guiana issued in 1885 "will probably assist in developing a demand for this material," while the fact is that balata has been going down in the estimation of manufacturers since that date in consequence of it having been found not to be durable when exposed to the air; manufactured articles made from it cracked on the surface, and the inner portion lost its tenacity, so that some manufacturers have given up its use entirely. The Dika plant of W. Trop. Africa, which has long been identified with the Simarubeous plant (*Irvingia Barteri*), is referred to under the very old name of *Mangifera Gabonensis*, a genus belonging to the natural order Anacardiaceæ. Again carapa or croupee oil of West Africa is said to be obtained from the seeds of *Carapa guineensis* and crab oil of British Guiana from *Carapa guianensis*. These two were combined by Prof. Oliver under *C. guyanensis* in the "Flora of Tropical Africa" so far back as 1868.

These are only a few illustrations of the general untrustworthiness of the essay, the circulation of which, it is hoped, will not be large.

THE ZODIACAL LIGHT.

FROM the days of Cassini a connection between the zodiacal light and sun-spots has been suggested. In some recent discussions it is denied. But, so far as I am able to discover, the long series of observations by Heiss and Weber, extending from 1847 to 1883, afford the first opportunity to attack the question.

The result is in the diagram before you. The broken line represents Wolf's well-known series of relative sun-spot numbers, the jagged full line the mean elongations